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RESEARCH MEMORANDUM

LATERAL-CONTROL INVESTIGATION OF FLAP-TYPE CONTROLS ON A
WING WITH UNSWEPT QUARTER-CHORD LINE, ASPECT RATIO 4,
TAPER RATIO 0.6, AND NACA 65A006 AIRFOIL SECTION

TRANSONIC-BUMP METHOD

By Alexander D. Hammond

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RESEARCH MEMORANDUM

LATERAL-CONTROL INVESTIGATION OF FLAP-TYPE CONTROLS ON A
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SUMMARY

As part of an NACA research program, an investigation by the transonic-bump method through a Mach range of 0.7 to 1.15 has been made in the Langley high-speed 7- by 10-foot tunnel to determine the lateral-control characteristics of 30-percent-chord flap-type controls having various spans and spanwise locations. The wing of the semispan fuselage-wing combination had an unswept quarter-chord line, a taper ratio of 0.6, an aspect ratio of 4.0, and an NACA 65A006 airfoil section parallel to the free air stream.

Rolling moments, pitching moments, and lift were obtained through a small range of control deflections. The majority of the data are presented as control-effectiveness parameters to show their variation with Mach number. In the Mach number region of 0.80 to 1.0, the results show a decided decrease in the lift-effectiveness and aileron-effectiveness parameters and a relative smaller decrease in the negative values of the pitching-effectiveness parameters.

INTRODUCTION

The need for aerodynamic data in the transonic speed range has led to the establishment of an integrated program for transonic research. As part of the NACA transonic research program, a series of wing-fuselage configurations having wing plan form as the chief variable are being investigated in the Langley high-speed 7- by 10-foot tunnel by using the transonic-bump method.

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This paper presents the results of a lateral-control investigation of a semispan wing-fuselage model employing a wing with an unswept quarter-chord line, an aspect ratio of 4.0, taper ratio of 0.6, and an NACA 65A006 airfoil section parallel to the free air stream. The purpose of this investigation was to obtain lateral-control data with flap-type controls of 30 percent chord, having various spans and spanwise locations. The results of a previous investigation of the same wing-fuselage configuration without controls may be found in reference 1. Data obtained in previous lateral-control investigations of a series of wings having the same aspect ratio, taper ratio, and airfoil sections as the wing of the present investigation and having the quarter-chord line sweptback 35° , 45° , and 60° are reported in references 2, 3, and 4, respectively.

MODEL AND APPARATUS

The semispan wing had zero angle of sweepback referred to the quarter-chord line, a taper ratio of 0.6, an aspect ratio of 4.0, and an NACA 65A006 airfoil section (reference 5) parallel to the free air stream. The wing was made of beryllium copper and the fuselage of brass. A two-view drawing of the model is presented in figure 1, and ordinates of the fuselage of fineness ratio 10 can be found in table I of reference 1.

The controls (aileron or flap) were made integral with the wing by cutting grooves 0.03 inch wide along the 70-percent-chord line on the upper and lower surfaces of the wing (fig. 2). The entire control from fuselage to wing tip was divided into four equal spanwise segments as shown in figure 2. After setting the control at the desired deflection by bending the metal along the grooves, the grooves and gaps were filled with wax, thus giving a close approach to a 30-percent-chord sealed plain flap-type control surface.

The model was mounted on an electrical strain-gage balance enclosed in the bump and the lift, pitching moments, and rolling moments about the model plane of symmetry were measured with a calibrated potentiometer.

COEFFICIENTS AND SYMBOLS

- C_L lift coefficient $\left(\frac{\text{Twice lift of semispan model}}{qS} \right)$
- C_l rolling-moment coefficient at plane of symmetry corrected for reflection-plane effects $\left(\frac{\text{Rolling moment of semispan model}}{qSb} \right)$

C_{l_u}	uncorrected rolling-moment coefficient
C_m	pitching-moment coefficient referred to $0.25\bar{c}$ $\left(\frac{\text{Twice pitching moment of semispan model}}{qS\bar{c}} \right)$
q	effective dynamic pressure over span of model, pounds per square foot $\left(\frac{1}{2}\rho V^2 \right)$
S	twice wing area of semispan model, 0.125 square foot
b	twice span of semispan model, 0.707 foot
\bar{c}	mean aerodynamic chord of wing, 0.180 foot $\left(\frac{2}{3} \int_0^{b/2} c^2 dy \right)$
c	local wing chord, feet
y	spanwise distance from plane of symmetry
y_i	spanwise distance from plane of symmetry to inboard end of control
ρ	mass density of air, slugs per cubic foot
V	free-stream air velocity, feet per second
M	effective Mach number over span of model
M_a	average chordwise local Mach number
M_l	local Mach number
R	Reynolds number of wing based on \bar{c}
α	angle of attack, degrees
δ	control deflection relative to wing-chord plane, measured perpendicular to control hinge axis (positive when trailing edge is down), degrees
b_a	control span measured perpendicular to plane of symmetry

$$C_{L\delta} = \left(\frac{\partial C_L}{\partial \delta} \right)_{\alpha}$$

$$C_{l\delta} = \left(\frac{\partial C_l}{\partial \delta} \right)_{\alpha}$$

$$C_{m\delta} = \left(\frac{\partial C_m}{\partial \delta} \right)_{\alpha}$$

The subscript α indicates that the angle of attack was held constant.

CORRECTIONS

The aileron-effectiveness parameters herein represent the aerodynamic effects on a complete wing produced by the deflection of the control on only one semispan of the complete wing. Reflection-plane corrections have been applied to the aileron-effectiveness parameters throughout the Mach range tested. The correction factors which were applied are given in figure 3. The values of the correction factors given in figure 3 were obtained from unpublished experimental low-speed data and theoretical considerations. Although the corrections are based on incompressible conditions and are only valid for the low Mach numbers, it was believed that the results obtained by applying the corrections would give a better representation of true conditions than uncorrected data.

The lift-effectiveness and pitching-effectiveness parameters represent the aerodynamic effects of deflection in the same direction of the controls on both semispans of the complete wing, and hence no reflection-plane corrections are necessary for the lift and pitching-moment data.

No corrections were applied for any twisting or deflection of the wing or controls caused by air load. However, based on static tests made on the wings of references 2 and 4 the effects were believed to be negligible.

TEST TECHNIQUE

The tests were made in the Langley high-speed 7- by 10-foot tunnel by use of an adaptation of the NACA wing-flow technique for obtaining transonic speeds. The technique used involves placing the model in the high-velocity flow field generated over the curved surface of a bump on the tunnel floor (reference 6).

Typical contours of local Mach number in the vicinity of the model location on the bump with model removed are shown in figure 4. The contours indicate that there is a Mach number variation of about 0.05 over the model semispan at low Mach numbers and from 0.07 to 0.08 at higher Mach numbers. The chordwise variation is generally less than 0.01. The effective Mach number over the wing semispan is estimated to be 0.02 higher than the effective Mach number where 50-percent-span outboard ailerons normally would be located. No attempt has been made to evaluate the effects of this chordwise and spanwise Mach number variation. The long-dash lines near the root of the wing in figure 4 indicate a local Mach number 5 percent below the maximum value and represent the estimated extent of the bump boundary layer. The effective test Mach number was obtained from contour charts similar to those presented in figure 4 by using the relationship

$$M = \frac{2}{S} \int_0^{b/2} cM_a dy$$

Force and moment data were obtained with controls of various spans through a Mach number range of 0.70 to 1.15, an angle-of-attack range of -6° to 6° ; and at control deflections of 0° , 5° , and 10° . The variation of Reynolds number with Mach number for these tests is shown in figure 5.

RESULTS AND DISCUSSION

The variations of lift, rolling-moment, and pitching-moment coefficients with control deflection up to 10° for the outboard 43-percent-span control at a wing angle of attack of 2° are presented in figures 6, 7, and 8. Since the wing was symmetrical, data obtained at negative angles of attack and positive control deflection were considered, with due regard to signs, to be equivalent to data that would be obtained at positive angles of attack and negative control deflections and were plotted as such. The curves of figures 6 to 8 are typical of the curves of each of the other control configurations tested.

The control-effectiveness parameters of figures 9 to 11 were obtained from figures 6 to 8 and similar plots of the test data for the various control configurations. The control-effectiveness for all configurations had nearly linear variation with control deflection for the deflection range of $\pm 10^\circ$, except in the Mach number range from 0.85 to 1.00. Because an insufficient number of small deflections were tested to obtain the slope near zero deflection, the effectiveness

parameters were determined from average slopes through the deflection range of $\pm 10^\circ$ for all Mach numbers.

A marked decrease in aileron and lift effectiveness occurs between Mach numbers of 0.80 and 1.0 and a smaller decrease in the negative values of pitching-effectiveness parameter occurs in the same Mach number region (figs. 9 to 11).

The effectiveness of controls of various spans starting at the tip (fig. 12) indicates that the outboard 21-percent-span control gives high aileron effectiveness when compared to an inboard control of the same span. Although there are considerable differences in aileron effectiveness for a given span control with increasing Mach number, in general the curves have the same shape. This would indicate that the relative effectiveness of a partial-span control to a full-span control is little affected by Mach number. On the other hand, the pitching-effectiveness data (figs. 11 and 12) indicate greater relative loss in effectiveness at supersonic Mach numbers for controls near the wing tip than for controls near the root.

The experimental values of $C_{l\delta}$ for $M = 0.70$ and 0.80 are compared (fig. 13) with the theoretical values of $C_{l\delta}$ for $M = 0.70$ estimated by means of the methods of reference 7 and by modifying the wing geometric characteristics and the rolling-moment coefficients for the effects of compressibility. The effects of compressibility on wing geometric characteristics were accounted for by the Glauert-Prandtl transformation (reference 8) and the effects of compressibility on the values of $C_{l\delta}$ were accounted for by the following equation:

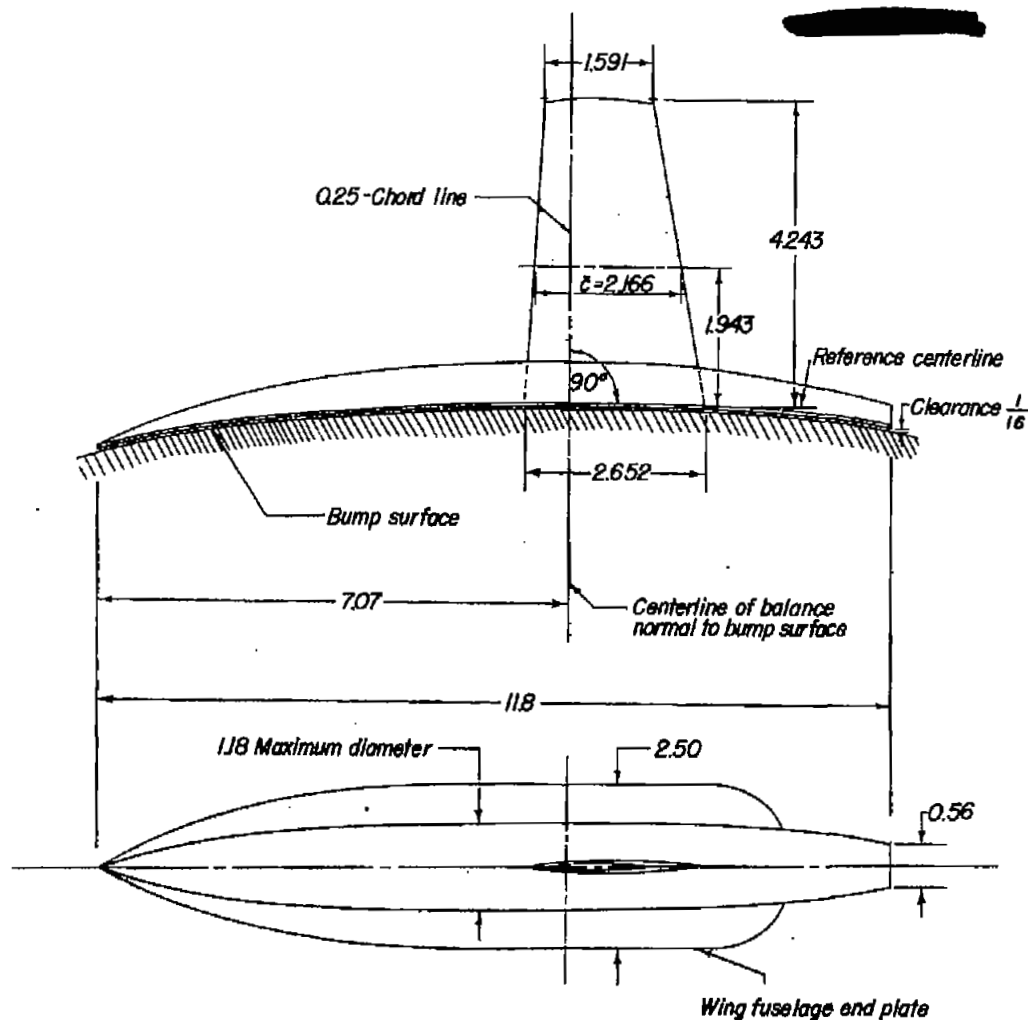
$$C_{l\delta} = \frac{C_{l\delta}'}{\sqrt{1 - M^2}}$$

where $C_{l\delta}'$ is the aileron-effectiveness parameter estimated by the methods of reference 7 after modifying the wing geometric characteristics by the Glauert-Prandtl transformation. The results show good agreement for the controls-tested.

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7. Lowry, John G., and Schneider, Leslie E.: Estimation of Effectiveness of Flap-Type Controls on Sweptback Wings. NACA TN 1674, 1948.
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TABULATED WING DATA

Area (twice semispan)	0.125 sq ft
Mean aerodynamic chord	0.180 ft
Aspect ratio	4.0
Taper ratio	0.6
Incidence	0.0°
Dihedral	0.0°
Airfoil section parallel to free airstream	NACA 65A006

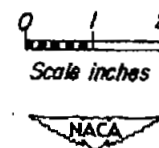


Figure 1.- General arrangement of model with 0° sweptback wing, aspect ratio 4, taper ratio 0.6, and NACA 65A006 airfoil.

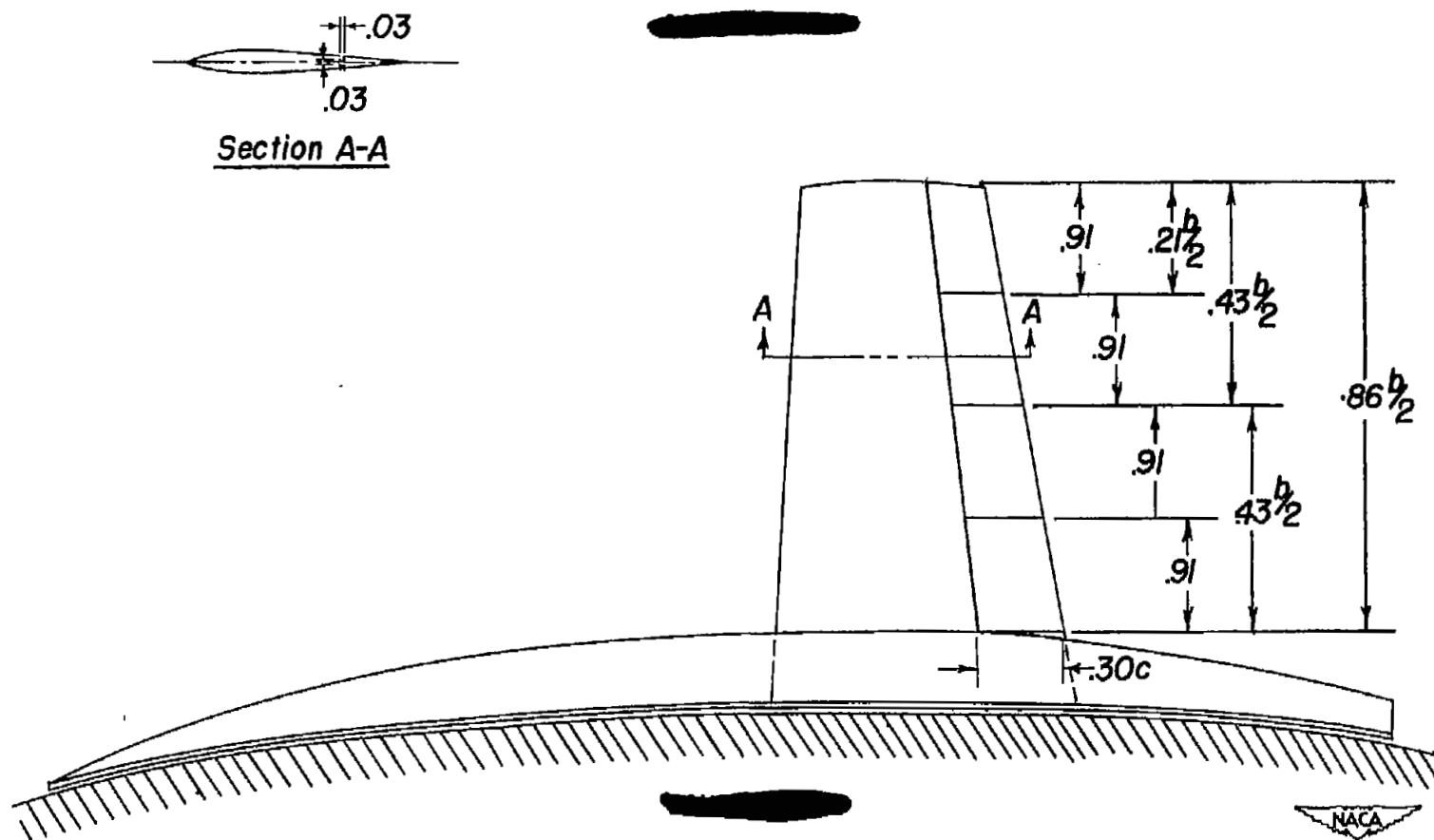


Figure 2.- Details of controls tested.

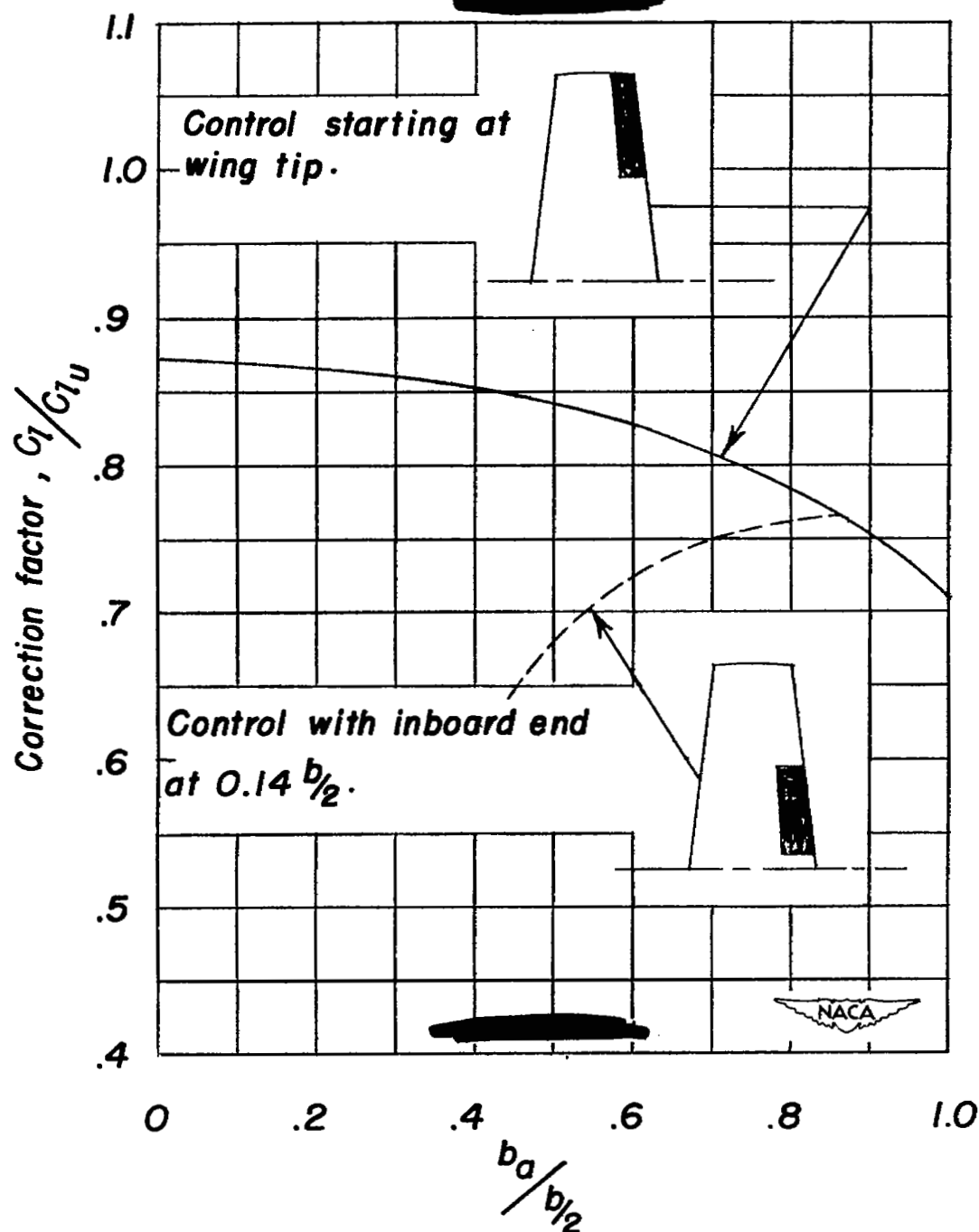


Figure 3.- Reflection-plane correction factors for inboard and outboard controls of various spans for a wing of 0° of sweepback, aspect ratio 4, and taper ratio of 0.6.

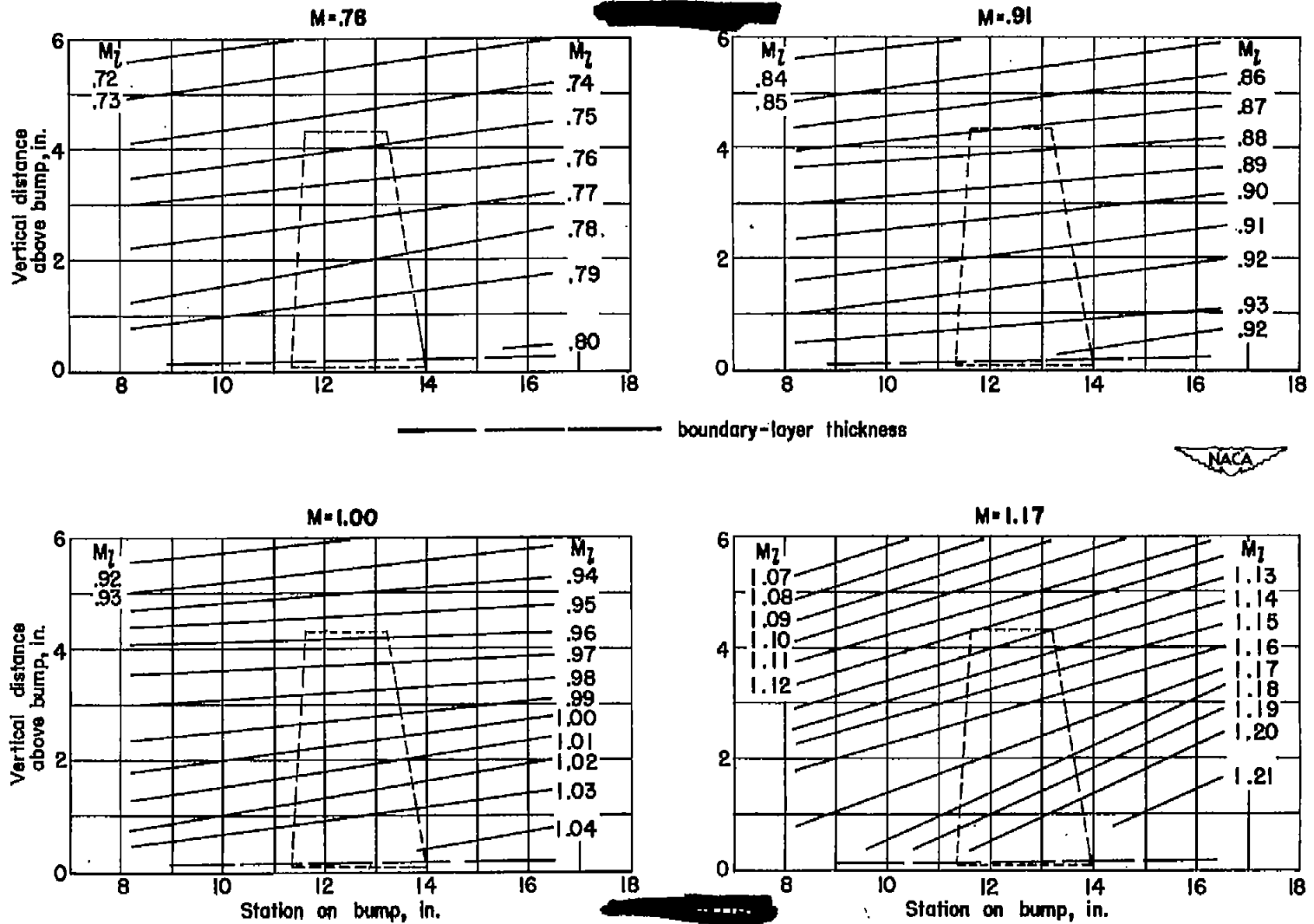


Figure 4.- Typical Mach number contours over transonic bump in region of model location.

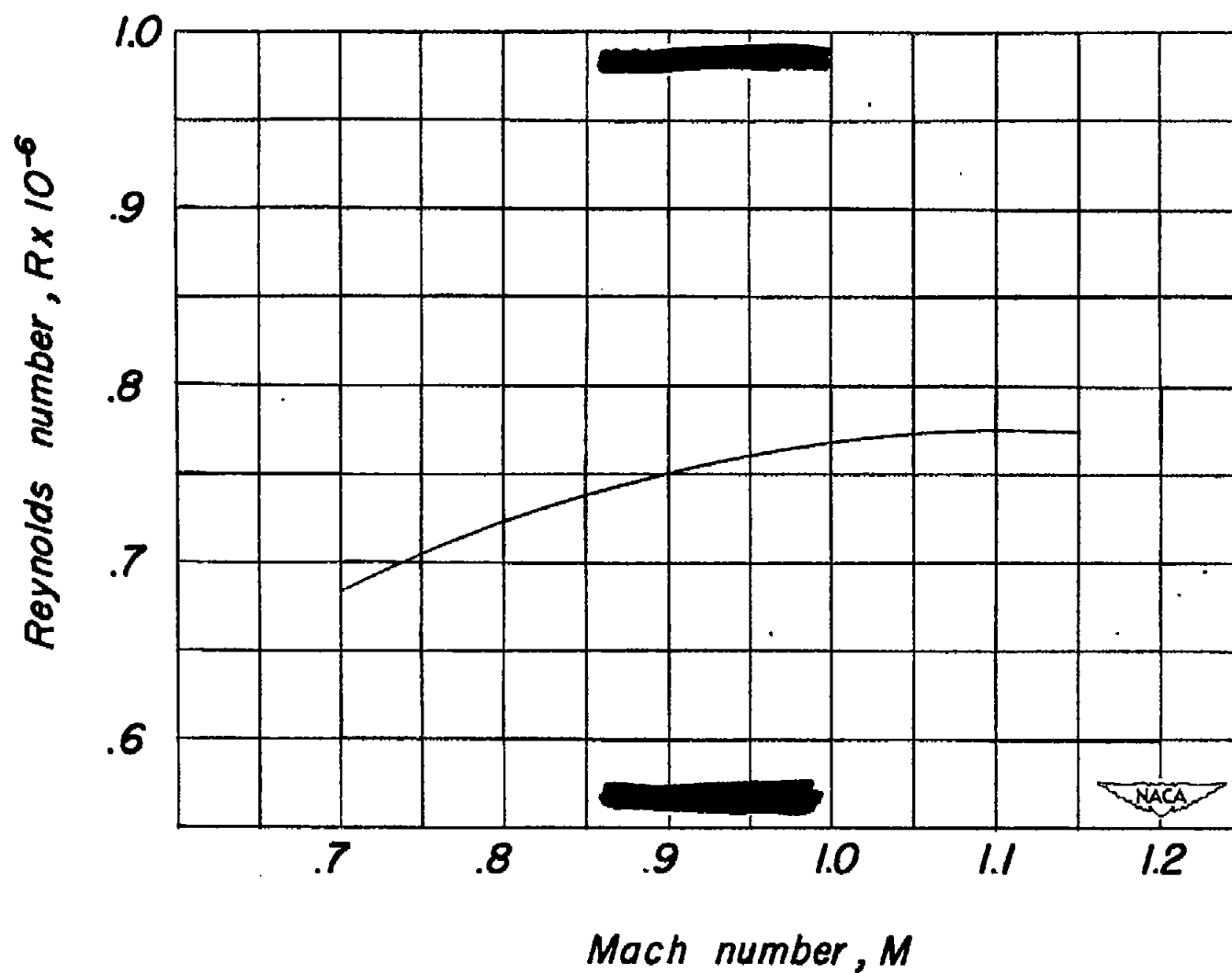


Figure 5.- Variation of test Reynolds number with Mach number for model with 0° sweptback wing, aspect ratio 4, taper ratio 0.6, and NACA 65A006 airfoil.

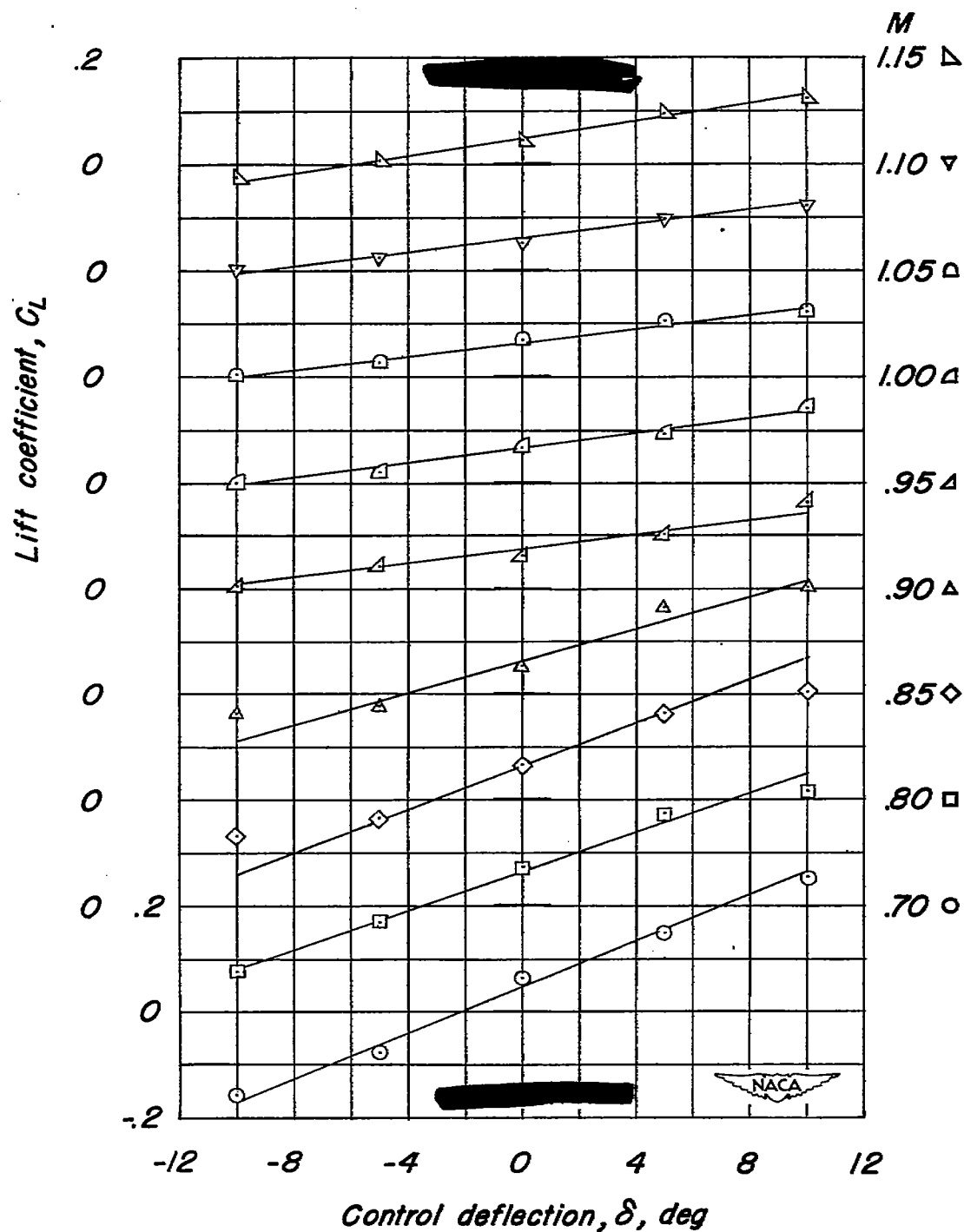


Figure 6.- Variation of lift coefficient with control deflection for various Mach numbers. $b_a = 0.43 \frac{b}{2}$, outboard; $\alpha = 2^\circ$.

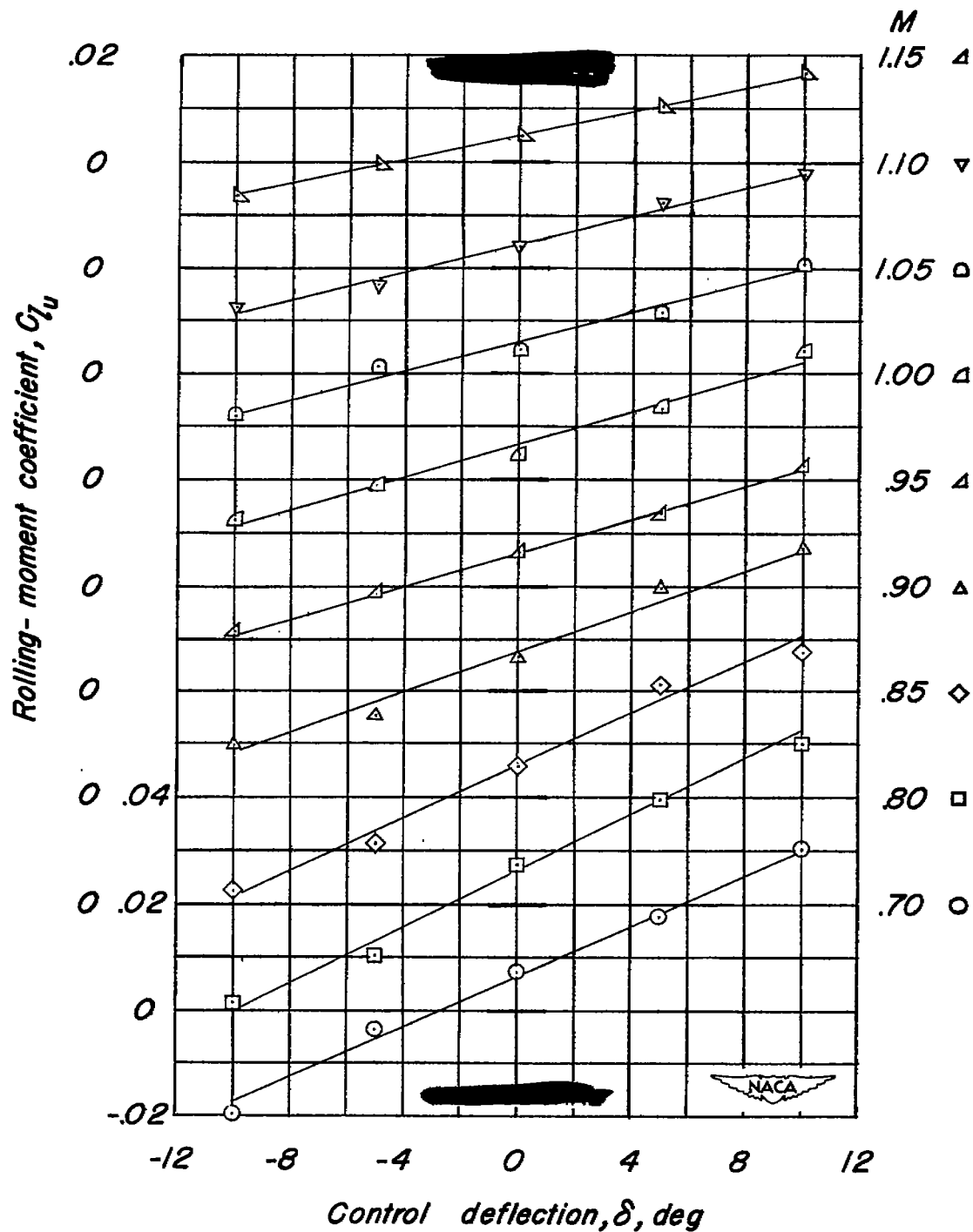


Figure 7.- Variation of rolling-moment coefficient with control deflection for various Mach numbers. $b_a = 0.43 \frac{b}{2}$, outboard; $\alpha = 2^\circ$.

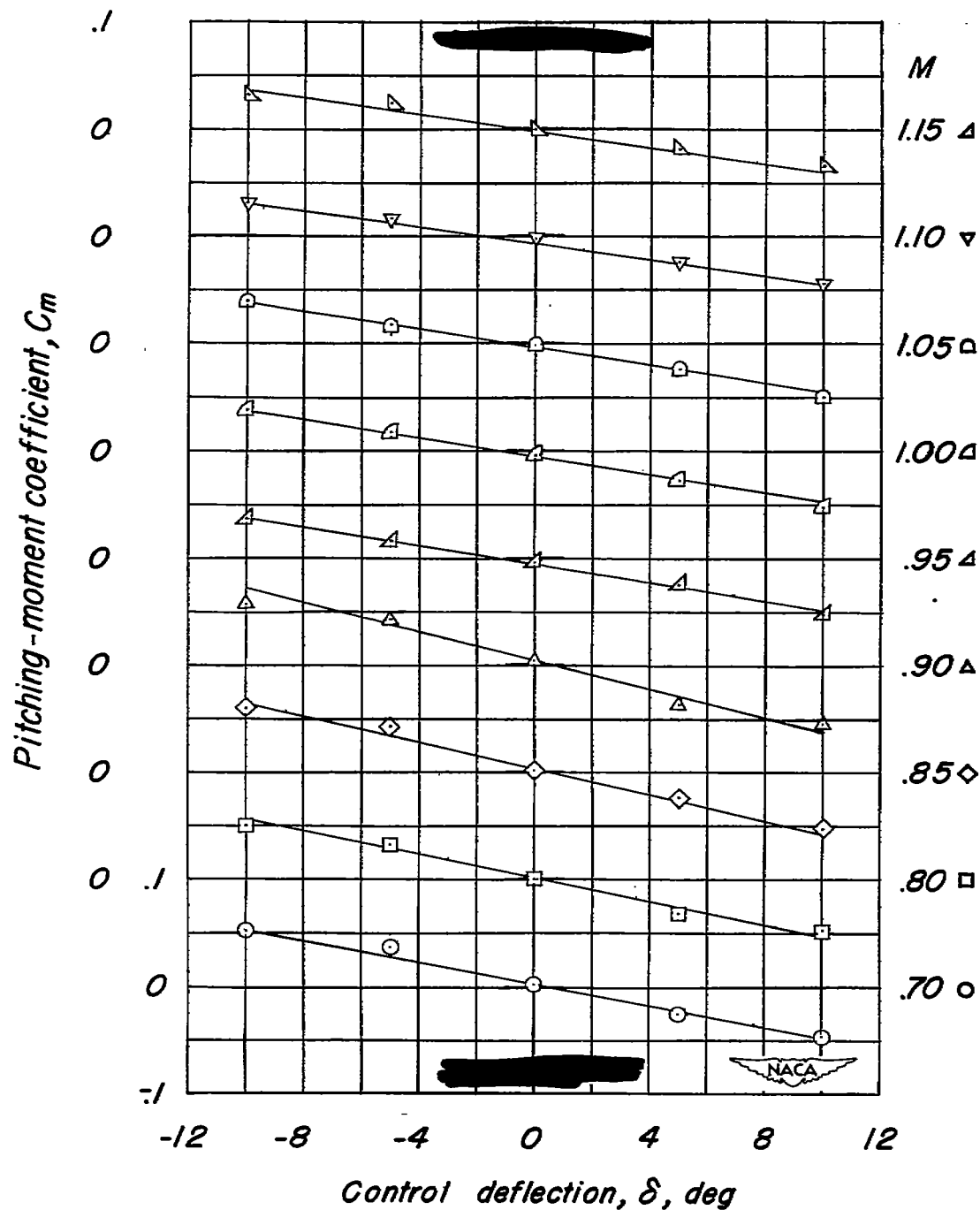


Figure 8.- Variation of pitching-moment coefficient with control deflection for various Mach numbers. $b_a = 0.43 \frac{b}{2}$, outboard; $\alpha = 2^\circ$.

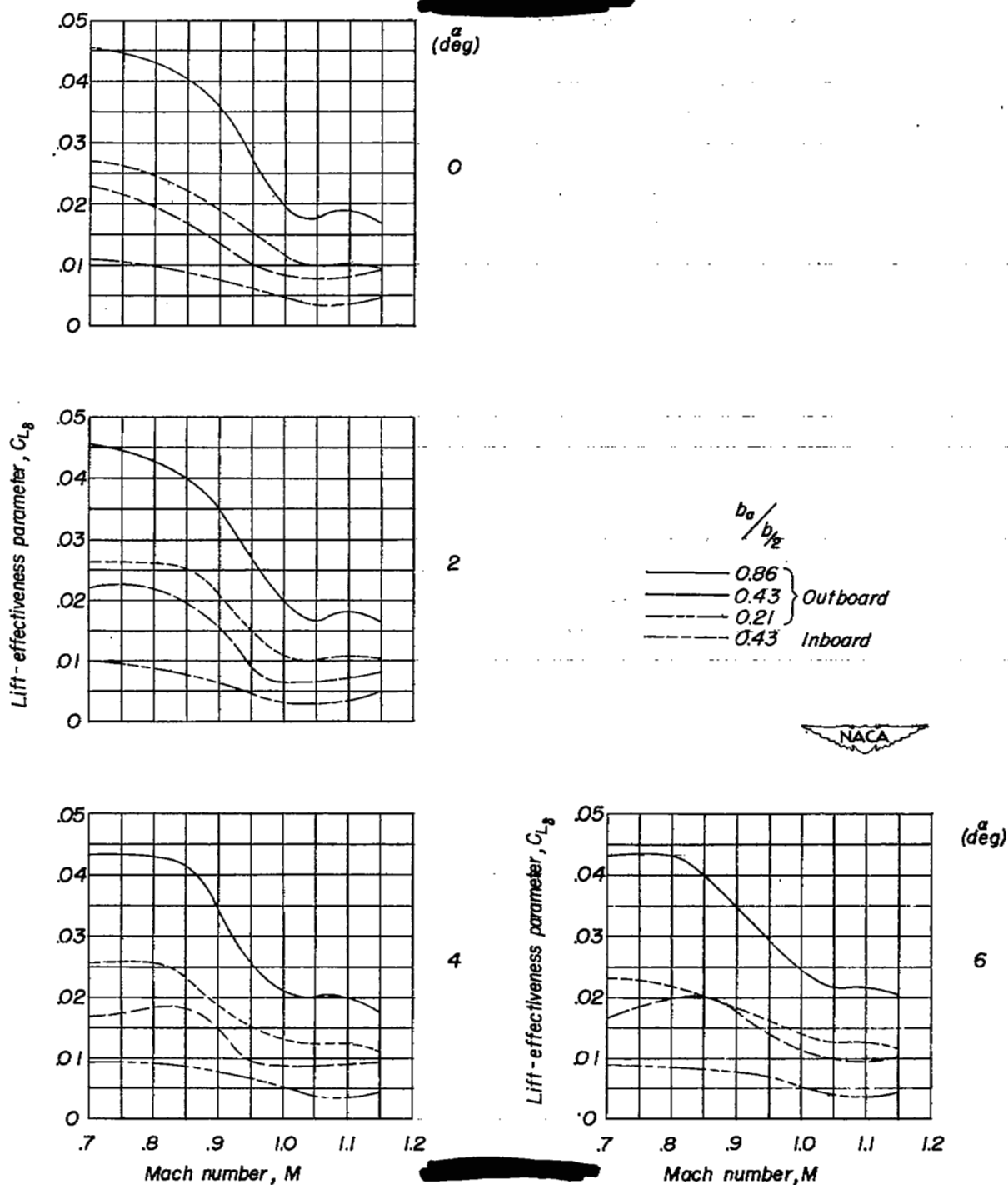


Figure 9.- Variation of lift-effectiveness parameter with Mach number.

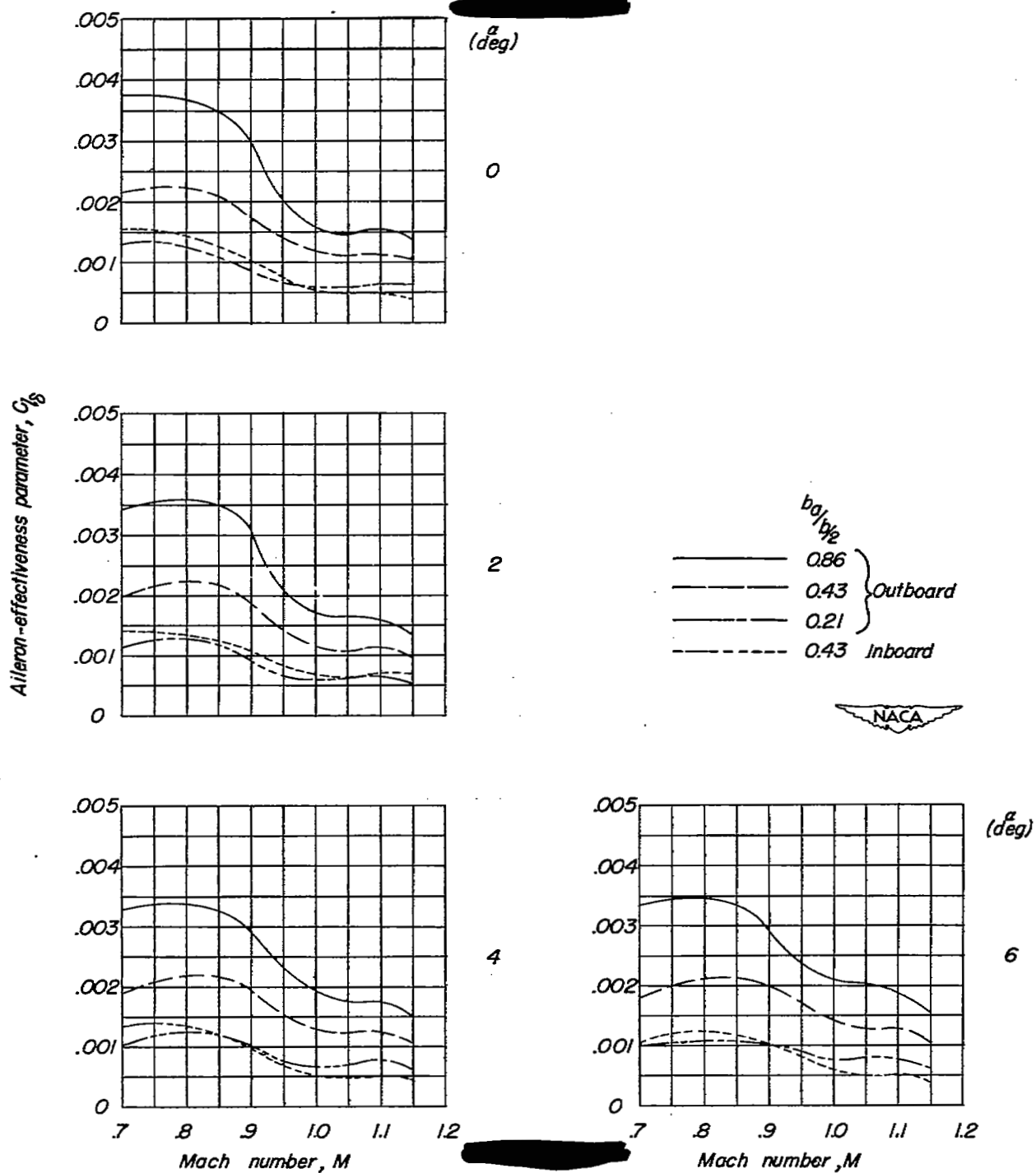


Figure 10.- Variation of aileron-effectiveness parameter with Mach number.

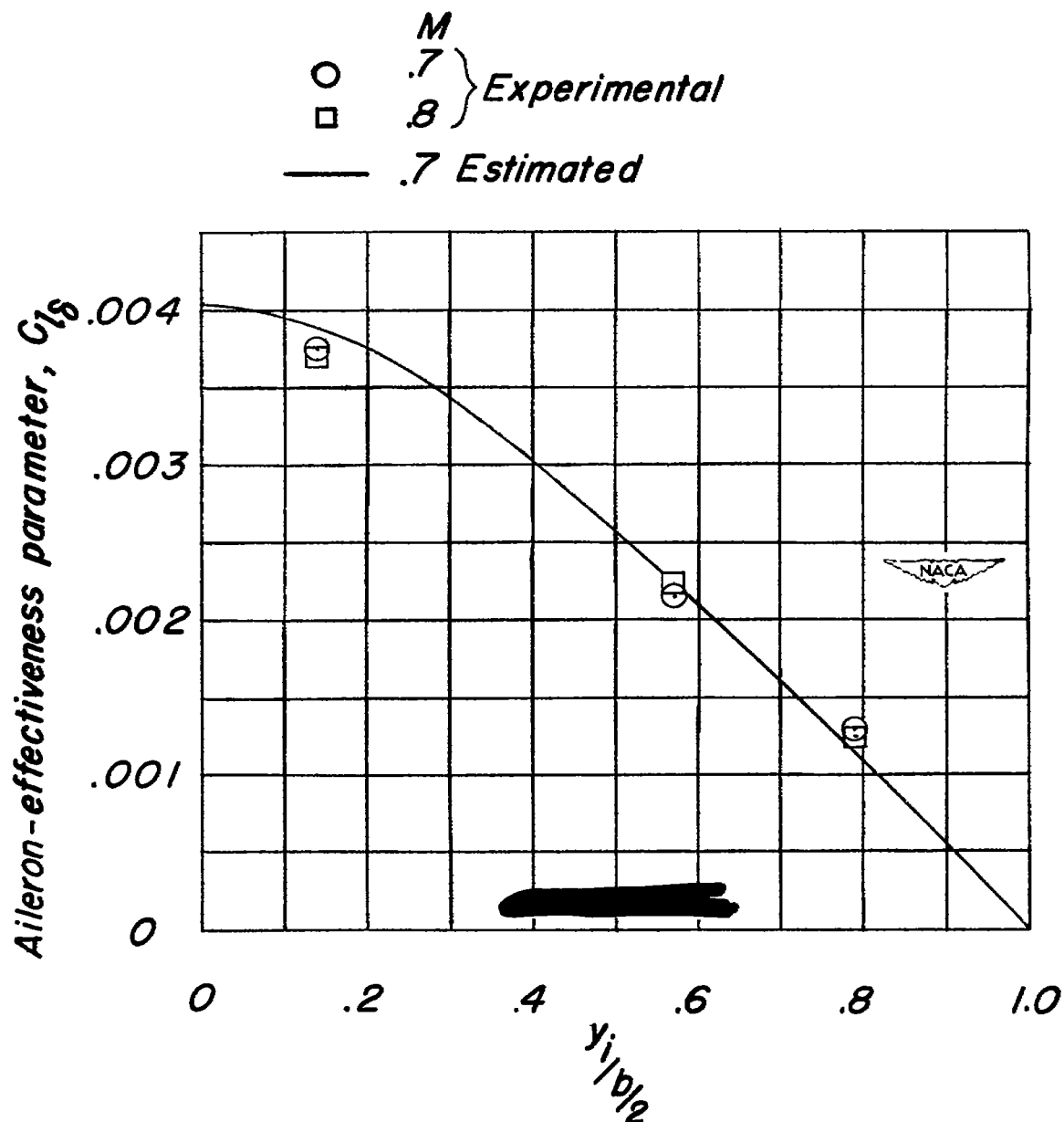


Figure 13.- Comparison of the experimental and estimated variation of aileron effectiveness with control span. $\alpha = 0^\circ$.



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